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SOME PROBLEMS OF TYPIFICATION AND UNIFICATION
OF DEVICES FOR TECHNOLOGICAL CONTROL AND
REGULATION USING NUCLEAR RADIATION

By

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An important role in solving many problems of complex industrial mechanization and automation in the USSR is played by devices for technological control using nuclear radiation.

As is well known, the automation of industrial technological processes is based on the extensive use of typified assemblies, units, production lines, etc. Work on the typification of radioactive devices for automatic control and regulation has been carried on for the last few years.

Among the highly diversified specialized technological control devices based on the application of radioactive radiation, typification principles have found the widest application in position-control and regulation equipment using relay-action devices, and in gauges for measuring the thickness and density of coatings employing differential and compensation circuits.

Position-control methods using radioactive isotopes are based on registering drastic changes in the intensity of radioactive radiation absorbed or scattered by the medium irrespective of the specific features of the parameter controlled. The accuracy of estimating the parameter controlled with the aid of relay-action devices depends slightly, if at all, on the intensity of the radiation registered.

Proceeding from this general principle of action, it is possible to work out general principles for designing record-

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ing devices which would allow to carry out the typification of their individual elements. A characteristic feature of radioactive relay-action devices which greatly influences their principal characteristics such as sensitivity, response and reliability, consists in fluctuation processes arising in the devices and associated with the statistical nature of radioactive radiation. Therefore general-purpose relay-action devices designed to handle a great diversity of problems in various industries contain electrical adjustment elements which permit setting up an optimum regime of device operation under the specific conditions of the process controlled.

Typified relay-action devices operate in the regime of registration of average current of a radiation detector (low-voltage, gas-discharge, halogen counters).

The principle of typification of relay-action devices consists in dividing them into three separate typified elements: radiation sources, radioactive sensing elements containing a radiation detector, and general-purpose electronic relay units.

Devices of different designations are provided with different sensing elements which are specialized. The design of the sensing elements ensures a maximum versatility of their utilisation in solving typical technological problems in various industries.

By way of example, below we describe some specimens of typified assemblies of relay-action equipment.

The radioactive detectors (1) and (2) in Fig. 1 are designed to register hard beta and soft gamma radiation. They are employed in controlling, counting and interlocking devices. Such detectors are widely used, for instance, in arrangements

which control the filling of containers regardless of the nature of the product contained in them, keep account of the output of stamping and pressing equipment, ensure protective interlocking of multiposition automatic presses, etc. These detectors are used in the chemical, food, mechanical engineering and other industries.

The radioactive detector 3 (Fig.I) is used in devices for radioactive labelling of steel wire butt welds. To secure a reliable control during the passage of separate wire coils in unmultiple - drawing machines, the weld butts of the wire coils are labelled with radioactive phosphorus - 32. The detector 3 is set up before the last die; it contains gas-discharge counters which register the passage of the labelled weld butt. Registering devices control a multiple - drawing machine and electromechanical shears for coil separation. The detector is used in the metallurgical industry.

The radioactive detectors (4), (5) and (6) (Fig.I) are employed in devices for position control of the level of liquid and loose materials. The detector 4 is designed to register hard beta radiation and serves to control the filling of measuring vessels with liquids. It consists of a metal cylinder provide with a counter with a beta source rigidly attached to it by means of a bracket.

The detector is immersed in the vessel to a preset depth. The level is controlled by the attenuation of the radiation due to the presence of the liquid layer between the source and the counter.

The detector (5) is designed for directional registration of gamma radiation. It is used in devices controlling

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the level of a liquid by means of a radioactive float with Co^{60} or Cs^{137} sources. The detector consists of a metal body containing a halogen counter and a one sided widge-type lead collimator. The detector is attached by means of a flange on the external side of the vessel at a preset filling level.

The detector (6) is designed to register gamma radiation in gauges controlling the level of liquid, loose and lump materials by gamma-raying vessels filled with them. It contains a number of gas-discharge halogen counters located in one plane. This device is used in gauges for technological level control in various industries: chemical, mining, ore-dressing, construction materials, etc.

In addition to the above-enumerated instruments, unified sensing devices of several types are produced which are designed for contactless three-position registration of the readings of measuring instruments of various types (needle instruments, flowmeters, liquid thermometers, etc).

No. 7 in Fig. I denotes a general-purpose electronic relay unit which is used in relay-action devices.

Typified assemblies for relay-action devices are produced in three types: normal, explosion - proof and airtight.

Methods for contactless control of thickness and coating thickness and density are based essentially on two types of continuous-action devices. Devices of the first type are based on a differential circuit for comparing the material controlled with a standard specimen, and are designed to control materials in continuous tech-

nological processes. Devices of the second type are built as self-compensation circuits with continuous counting of the parameter controlled, and are meant for material control both in continuous and intermittent technological processes.

Both types of instruments mostly use ionization chambers as radiation detectors. They are characterized by high versatility and a wide range of the values measured, and may be employed for controlling materials which differ in their chemical and physical properties.

Use of beta radiation requires open ionization chambers; in the case of gamma radiation high-pressure chambers are employed. Scintillation counters with current conditions of electronic photomultiplier operation are also used occasionally.

Fig. 2 shows the functional diagram of a device of the first type. The difference in the currents induced by two radiation fluxes is measured by means of a differential ionization chamber consisting of two electrically cross-connected compartments (1 and 2) with a high - ohmic resistor(3). One flux from the source (4) passes through the material controlled (5) and enters the principal compartment (1). The other flux from the auxiliary source (6) enters the compartment (2) through the standard specimen of the material controlled (7). The differential current is intensified by one amplification cascade (8) operating in an electrometric regime, and is fed to the measuring instrument (9). To eliminate the instability of zero count, the instrument is provided with a periodic self-adjustment

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arrangement which uses the above-described unified assemblies of relay devices. Periodically, once every 30 - 60 minutes, the time relay (10) switches the device circuit from the measuring to the self-adjustment regime. The switch (11) closes the input of the electrometric cascade. If the measuring instrument needle is not reset to zero, the beta radiation from the isotope located at the needle tip penetrates into one of the gas-discharge counters (12) installed behind the instrument scale and separated by the metal shield (13).

The counters are connected with the typified two-channel electronic relay unit (14) which phase-commutes the supply voltage of the windings of the servomotor (15). The latter is connected mechanically with the potentiometer which sets the measuring instrument to zero.

Self-adjustment takes about 1 minute, after which the instrument circuit automatically switches over to the measuring regime.

The circuit response is selected so that the needle deflection to the extreme left and right positions corresponds to the tolerance for the deviations of the parameter controlled. Signalling for the extreme positions of the needle is effected with the aid of the two counters (16) located at the extremes of the measuring instrument scale. The counters are connected with the typified two-channel electronic relay unit (17). The instrument is provided with terminals which connect it with a system for the regulation of the process controlled, a standard recording instrument and a sounding or light alarm which announces the overshooting

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of the parameter controlled. The general view of the device is given in Fig. 3.

The device consists essentially of two units: the radioactive detector (I) with a differential ionization chamber, and the measuring unit (2). The device operates without self-adjustment and requires periodic manual adjustment. The self-adjustment system includes two typified units: the time relay (3) and the two-channel electronic relay amplifier (4). The external signalization system supplements the device with another two-channel electronic relay unit (5). Three of the five principal units of the device are employed in relay-action instruments as typified assemblies. Therefore, plants which have mastered the production of relay-action devices, have easily handled small-scale production of such devices. The device is designed to control and measure the surface density of materials in the range from 10 to 10,000 gm/sq.m. The measurement accuracy is not below 1%.

Fig. 4 demonstrates the functional diagram of a device of the second type. This circuit also employs a differential ionization chamber.

The radiation from one of the sources (I) passes through the material controlled (2) and penetrates into the principal chamber compartment (3). The radiation from the auxiliary source (7) through the orificing shutter (6) enters the compartment (4).

The signal proportional to the differential current of both the chamber compartments is intensified by the amplifier (10) and fed to the servomotor (II) which shifts

the orificing shutter (6) until a complete equality of currents in both the chamber compartments is achieved. The position of the orificing shutter is registered by the indicator (12).

To eliminate the drift inherent to d.c. amplifiers, the device uses modulation (interruption) of the output signal of the chamber with the aid of the converter (9) followed by the a.c. amplifier (10).

Inasmuch as the device uses a differential ionization chamber, the instability of the chamber supply voltage and the pressure variations in both of its compartments do not affect the measurement results. Besides, the variations in the high-ohmic resistance and in the amplification factor of the amplifier do not introduce considerable errors into the measurement results, either.

The indicator (12) has the shape of a needle measuring instrument. The angle of needle deviation is a measure of the intensity of the radiation flux measured. The scale is calibrated in units of thickness or surface density of the materials measured.

The general view of the device is presented in Fig. 5. The device is designed for continuous measuring and recording of the surface density of sheet materials in the range from 10 to 10,000 gm/sq.m. The measurement accuracy is not below 1%. The device is provided with a terminal leading to the system of automatic regulation of the process controlled.

Both the types of devices may be used to measure coating thickness; in this case special sensing instruments are

employed whose function is based on backscattering of beta radiation. The other assemblies of the instrument remain unchanged.

The wide range of the values measured is attained by using a set of standard radioactive sources in both types of instruments.

Some of these sources are used in position-control devices as well.

Table I contains characteristics of typical radiation sources which have found the widest application in technological control devices.

Fig. 6 exhibits sketches of typical beta-source containers used in industrial technological control devices.

The work carried on in the USSR toward the typification and unification of devices for automatic control and regulation of industrial processes using radioactive radiations, and the industrial production of typified general-purpose units for them have allowed to proceed from single separate operations to complex automation and mechanization of large plants.

Thus, for instance, at the Mining and Milling Combine in Krivoy Rog over 60 relay-action devices have been installed which automatically control and regulate a great number of labour-consuming processes and operations.

The introduction of radioactive automation at the Combine has essentially improved labour conditions and ensured an economy of over 10 mln. roubles per year.

The utilization of devices for position control and regulation with radioactive sensing elements for the automation of underground works in the coal and mining indust-

ries is highly efficient. It allows to relieve a great number of underground workers.

The application of gauges measuring thickness, coating density and thickness, also ensures high economic efficiency.

Thus, the introduction of gauges for measuring the thickness of non-ferrous sheet metals at one of the Leningrad plants has allowed to reduce the expenditure of raw materials due to the reduction of tolerances and the decrease in rejections from 4.4 to 1.4%. Simultaneously the productivity of rolling machines has increased by 7%. The total annual economy at the plant amounts to 10 mln. roubles.

The reduction of tolerances for the thickness of sheet materials, such as paper, glass, plastics and others, by installing technological control instruments allows to greatly economize materials, to increase the productivity of the operating equipment, and provides conditions for switching over to completely automatized production in a number of industries: metallurgical, chemical, paper, etc.

The examples cited above reveal that the application of technological control devices using nuclear radiation has a great economic effect. According to the economists, of the total annual economy obtained in the USSR in 1958 due to the utilization of radioactive isotopes and nuclear radiation (1.6 - 1.8 mlrd. roubles), the radioactive automatic control devices contributed about 500 mln. roubles. during the same period.

We believe that in the near future the efforts will be directed at a further typification of instrument elements and the extension of typification principles to

devices for measuring liquid density, flow rate meters, pressure gauges, etc.

It has been estimated on the basis of the established technical possibilities and the scope of the prospective applications of radioactive devices for the automatic control and regulation of technological processes, that within the next few years the economic efficiency of their utilization in the national economy of the USSR will achieve a considerable magnitude.

Table 1

Isotope	Promethium-147	Thallium-204	Strontium-90, Yttrium-90	Zirconium-144, praseodymium-144	Thulium-170	Selenium-75	Cesium-137	Cobalt-60
Half-life	2.66 yrs	4.26 yrs	27.7 yrs	284 d	129 d	125 d	30 yrs	5.24 yrs
Type of radiation (used)	β	β	β	β	γ	γ	γ	γ
Radiation energy (used, MeV)	0.223	0.765	2.18	2.27	0.084	0.3	0.662	~1.25
Source activity (mc or mg-eq of radium)	1-100	1-100	0.02-100	1-100	2-100	10-100	0.1-500	0.1-500

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FIGURES

Fig. 1. Typical assemblies of relay-action devices.

1, 2, 3, 4, 5, 6 = radioactive detectors; 7 = general-purpose electronic relay block.

Fig. 2. Differential circuit for measuring material thickness and density with periodic self-adjustment using relay-action devices.

Fig. 3. General-purpose radioactive thickness and density gauge based on a differential circuit for comparing material controlled with standard specimen.

1 = radioactive detector; 2 = measuring unit; 3 = time-relay unit; 4,5 - typical two - channel electronic relay amplifiers.

Fig. 4. Self - compensation circuit for measuring material thickness and density.

Fig. 5. Radioactive general-purpose thickness and density gauge with continuous counting of parameter controlled.

1 = measuring unit; 2 = amplifier and supply circuit;
3 = indicating instrument.

Fig. 6. Standard beta- source containers.

1 = point source container; 2 = plane source container;
3 = linear source container.

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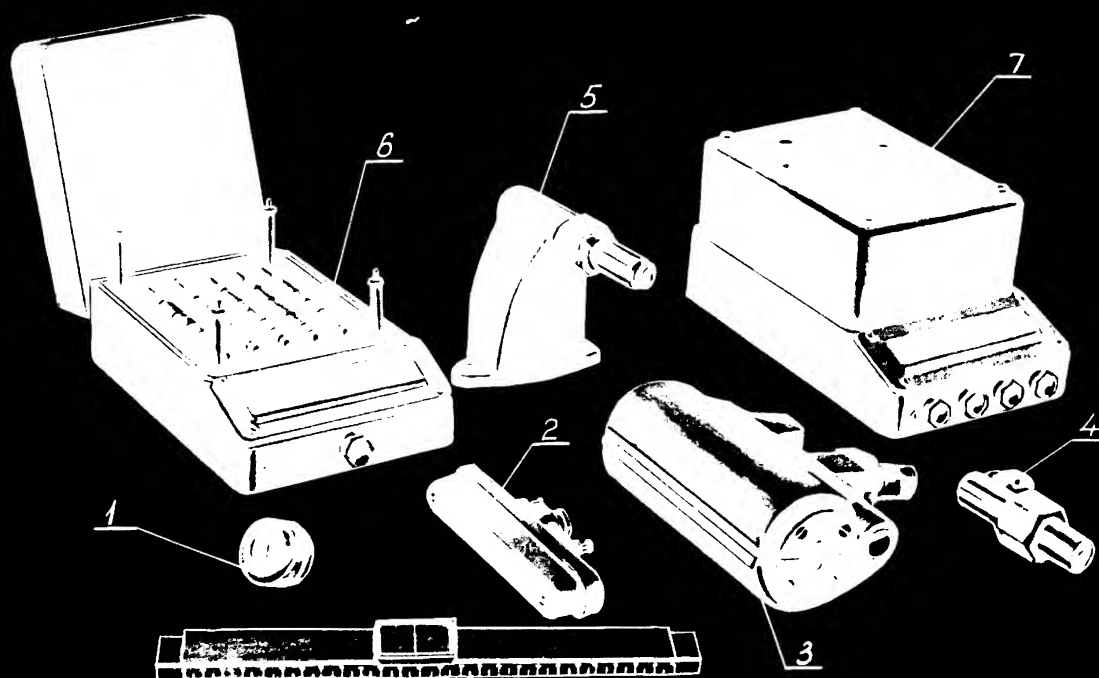
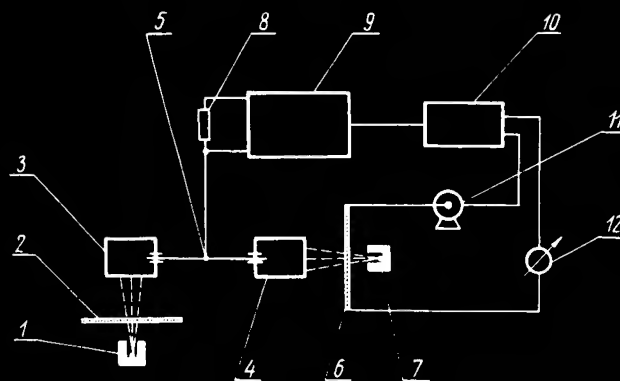
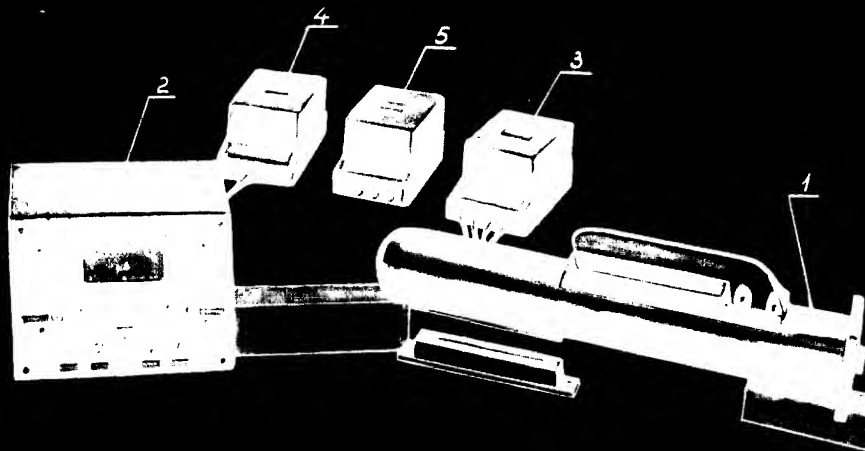
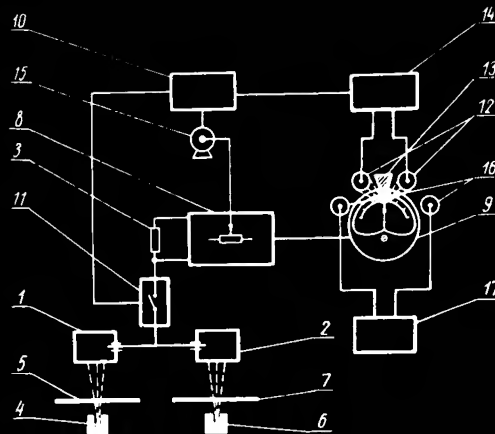


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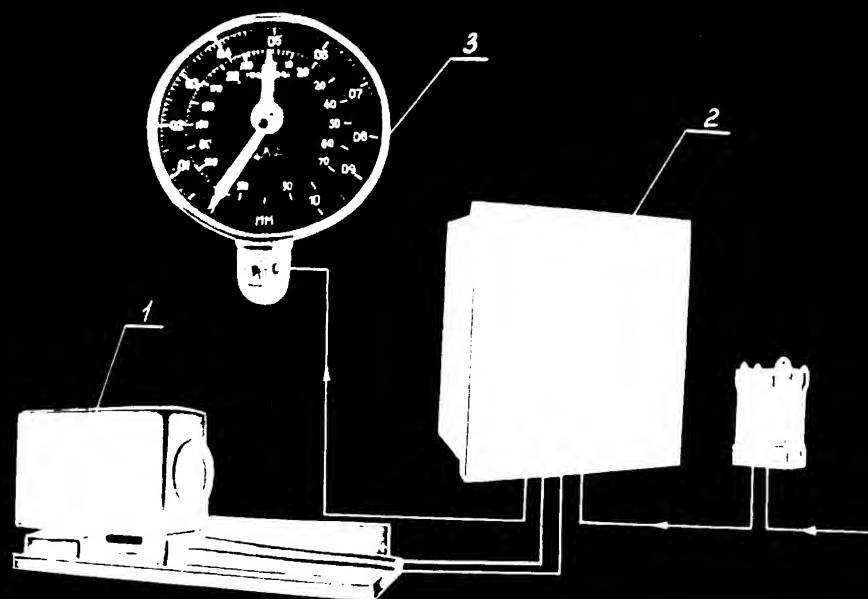


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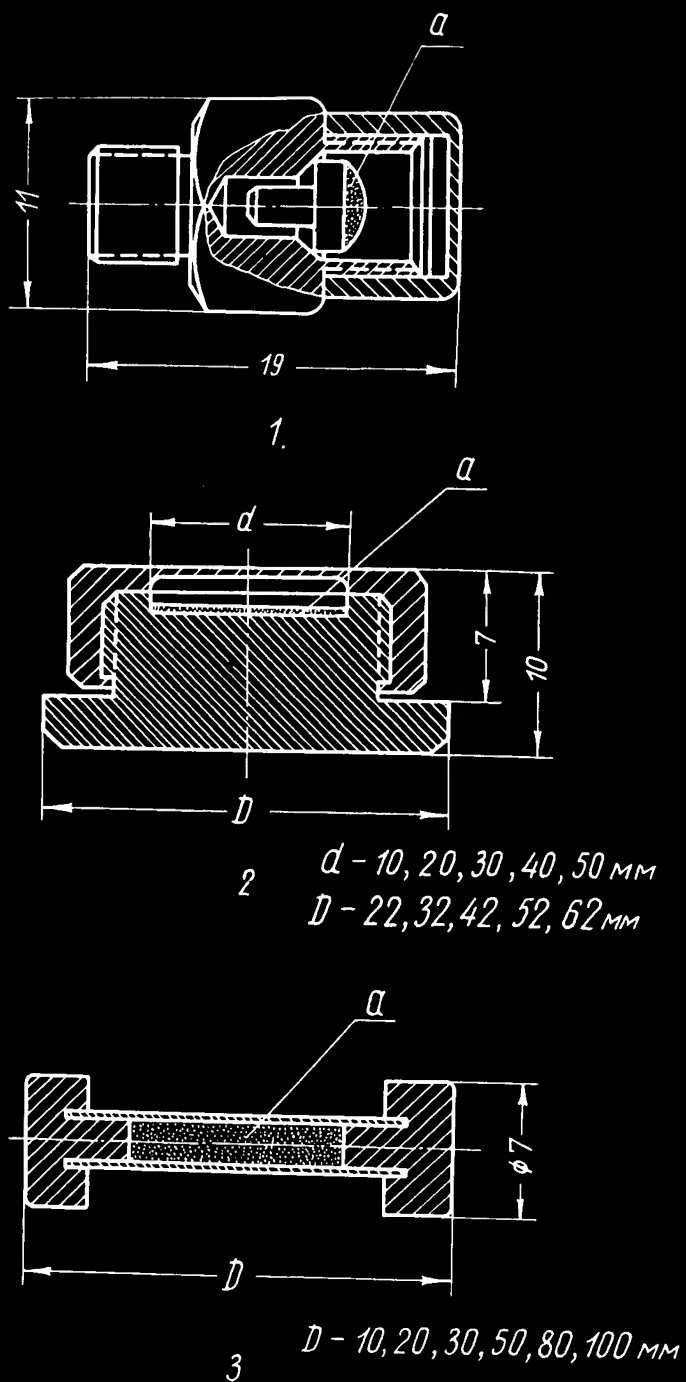


Рис. 6

THE USE OF RADIOACTIVE ISOTOPES AND NUCLEAR RADIATION
IN THE SOLUTION OF SOME PROBLEMS OF BLAST-FURNACE AND
STEEL-MAKING PRODUCTION

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The extensive organization of work in metallurgy, in which the attainments of nuclear physics have been utilized, in the USSR dates back to the years 1948-1949.

The Institutes and plants of the Ferrous Metallurgy have a network of radiometric laboratories for the inspection and development of technological processes.

Separate questions connected with the utilization of radioactive isotopes and nuclear radiation in the metallurgical industry of the Soviet Union have been described in the literature in detail. Some results have already been reported at international conferences. The present report deals only with individual examples of the utilization of radioactive isotopes and nuclear radiation in the ferrous metal industry. Chief attention is paid to the results of work now in progress at the Kuznetsk Iron and Steel Works, and the "Azovstal", the Dzerzhinsk, the Ilich and the Stalinsk Iron and Steel mills, with the collaboration of the Central Scientific Research Institute of the Ferrous Metal Industry.

I. BLAST-FURNACE PRODUCTION

1. Regulation of Incoming Charge in Blast-Furnaces

In the field of cast iron manufacture the automation of the control of the operation of the blast-furnace process

is an important problem. In this connection there arises the need to provide contactless, continuous-acting low-inertia data units, which afford data on the run of processes, as well as its transmission into the computer. In the solution of this problem in the Soviet Union great attention is paid to the utilization of radioactive isotopes. To that end there has been developed a radiometric installation designed for the regulation of blast-furnace incoming charge.

At the present time the blast-furnace incoming charge is regulated on the basis of indications of mechanical soundings, which give satisfactory results only when the blast-furnace runs smoothly. Sounding diagrams often do not characterize the position of the surface of the charge and do not permit to regulate the level of filling. Great difficulties are experienced when mechanical soundings are utilized in the operation of large volume blast-furnaces, when the pressure under the furnace top is raised.

The radioactive method regulating the level of filling of the blast-furnace with charge materials is based on the absorption of gamma-rays from radioactive sources. In the given case one may utilize radioactive isotopes of cobalt and other elements with a hard gamma-radiation (with energies of 1 MeV or more) and with a sufficiently large half-life (one year and more). Closed sources of radiation with activities of about 200 mcuries (depending upon ray hardness and furnace dimensions) are set up in the furnace refractory masonry at a definite level of fill of charge materials, or under the bell (Fig. 1). At various points along the furnace periphery in the refractory masonry radiation detectors (halogen counters) are

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installed, whose cables are connected to the recorder with a light panel. Detectors are set up on a number of horizons, four on each horizon. When the charge material level of fill is lower than the location of any one of the detectors, the irradiation intensity of the detector increases abruptly, and the respective signal lamp on the control board ignites.

The radiometric method of regulation of the level of filling is being used on one of the blast-furnaces of the Dzerzhinsk plant. The diagram of the radiometric regulator of the level of filling, developed by personnel of the plant, of CSRIFMI and of the Ukrainian Institute of Metals, is shown on Figures 1 and 2. In this case two sources of radioactive cobalt, 500 mcuries each, were placed on the blast-furnace, under the level of the material, along the furnace top circumference, between the vertical rows of counters (See Fig. 2). Sources and counters have been arranged in such a manner that the radiation of each source acts only upon the two vertical rows of counters, which are opposite to it. The possibility of shifting the sources in pipes permits to carry it out with facility.

A comparison of the readings of the radiometric installation and of the mechanical soundings leads to the following conclusions:

a. The readings of the installation from the side of the cast iron tap and air heaters rarely coincide with sounding data when the furnace runs very smoothly; as a rule, the readings of mechanical soundings are considerably lower than the surface of the fill, as revealed by radiometric control;

b. Due to the fact that the soundings are drawn in by the charge, the actual level of materials is in many cases higher

that the bottom position of the edge of the large bell; as a result, the orientation by mechanical sounding readings often leads to the overloading of furnaces. The passage to the control of the loading of furnaces by radiometric control data evens out the running of furnaces.

The new regulator of filling clearly manifests a nonuniform speed of incoming materials along the circumference.

The Dzerzhinsk Plant, CSRIFMI the Ukrainian Institute of Metals and the Tallin measuring instruments plant have worked out an industrial standard for the radiometric fill regulator. During the years 1959 and 1960 regulators will be installed on blast-furnaces at a number of plants.

2. Control of the Quality of the Charge and Ore

In order to control the blast duty a reliable and quick determination of the granulometric composition of the charge is needed. At some plants the screen composition of charge materials is determined by the screen sizing of samples weighing about one ton, selected in 24 hours. This very laborious method does not offer any possibility to obtain in the time allotted to it the necessary true results, which considerably lowers its validity.

The study of the absorption of gamma-radiation by the blast-furnace charge components carried out on the Dzerzhinsk and Novo-Tulsk Steel Plants revealed the possibility of controlling the gas-permeability of charge materials by the radiometric method. It has been found that the absorption of gamma-rays in that case depends upon the density, the bulk weight of the material connected with the screen composition. Personnel of the CSRIFMI and of the Dzerzhinsk Plant developed and manufactured three experimental devices for the measu-

rement of the lumping of coke, upon whose screen composition depends the general gas-permeability of the charge column (coke occupies about 60% of the charge volume).

The device has been installed at one of the blast-furnaces of the Dzerzhinsk Plant, at the left-hand weight funnel of the lift of the blast-furnace. The weight funnel a (Fig.3) is transluce by a radioactive isotope of cobalt (Co^{60}), with a 300 mcurie activity, situated in a protective collimator b, which may be displaced by guides, either bringing it closer to the funnel, or removing it from the funnel. The data unit d, located on the opposite side, from centres at the point e consists of eight CTC-6 counters. It measures the intensity of the beam of rays, which passes through the coke, which is recorded by a specially constructed recorder.

Coke lumping is recorded separately for each skip by its filling the weight funnel, simultaneously with the stoppage of the disk sieve, which delivers coke from the hopper into the funnel. In making records on the band appear "peaks" of the radiation intensity (Fig. 4) varying in size, depending upon the density of the material.

A comparison of records of the device, obtained at the Dzerzhinsk Plant, with readings of furnace operation, has revealed that the absorption of gamma-rays by coke varied from 5.0 to 12.7% of the mean value; at a minimum absorption the coke ore load reached 2540 kg/t and at a maximum it was lowered to 2210 kg/t., that is, it was lowered 13%. That does not agree with the existing ideas on the possible effect of coke lumping upon the thermal condition of the furnace and of coke consumption (the amount of carbon in the charge hardly changes thereby). Furnace operation observations reve-

aled that at periods of maximum absorption of gamma-rays by coke the extraction of coke out of the furnace with slag increases (not only with the lower, but also with the upper slag). Individual cast iron yields were followed by the carrying away of approximately up to 10-12 tons of coke with the lower slag; a considerable amount of coke fell into slag ladles through slag taps. Since the coke left the hearth heated to 1350-1400°C, the noticeable heat losses must be calculated. These fuel losses indicate that it is necessary to increase coke lumpiness in operating furnaces at an increased gas pressure, to pay a greater attention to the maintenance of cast iron caps and to the limitation of slag tuyere dimensions.

Blast-furnace output is in a considerable measure determined by the preparation of ore materials. In the solution of this problem the control of the process of iron ore refining and of agglomerate sintering is an important link. The utilization of radioactive isotopes has proved to be very effective in this field also.

At the Kuznetsk Iron and Steel Works a radiometer was designed for the determination of the agglomerate density. Instrument operation is based on the absorption of radioactive emission of isotopes. Instrument tests at the agglomerate plant have shown that it may be used for the control of the process of ore sintering in obtaining the agglomerate.

Further rationalization of the method and development of reliable installations for the control of the properties of coke, ore and agglomerate offer a possibility to obtain data in relation to the aerodynamic resistance of the charge. The use of radiometric installations for controlling the density of

coke, ore and agglomerate permits to increase blast-furnace output, and also creates new prerequisites for the automation of laborious processes and for the sanitation of the condition of labour.

3. Determination of the Speed of Motion and of the Time during which the Charge stays in the Blast-Furnace

For a number of years on several plants in the Soviet Union is the motion of charge materials in blast-furnaces controlled. This work is of great practical value for the control of the blast-furnace process and for the determination of optimal duties of furnace operation and of a rational shaft profile.

For the study of the motion of the charge by means of radioactive isotopes two particular methods are used. The first method (the method of measuring the radioactivity of tests of melt products) determines the total time during which the materials are in the furnace - from the instant of loading to their getting into the hearth and their dissolution in cast iron. In this case materials are carried into the furnace in the zone of the top at a definite time prior to the output of cast iron. The time of their getting into the hearth is established by the appearance of radioactivity in the cast iron. This method requires no special equipment, but it offers no possibility for the determination of the speed of the incoming charge on separate sections of the furnace shaft.

The time during which various charge materials stay at a desired point in the furnace was determined on furnaces of a variety of volumes and designs. Tests at the Novo-Tulsk Plant have shown that in the zone of the body and in the lower section of the shaft there is a ring of slowly-moving

materials, which lessens the actual working volume of the furnace by 10-15%. This information is partially corroborated by limestone tests at the "Azovstal" Plant. The mean speed of lowering materials, in a number of cases, was greater in the centre of the furnace than at the periphery - directly at shaft walls, which depends both upon the system of loading and upon the physical properties of charge materials. The relative alteration of the mean speed along radii of two furnaces of the "Azovstal" Plant is shown on Fig. 5. On the blast-furnace A the speed increases continuously from the periphery to the centre, while on the blast-furnace B it reaches a maximum at a distance about 0.46 m from the shaft wall, and becomes less and less thereon. In both cases the speed is higher in the centre than at the periphery.

The second method - of radiometric sondage (developed by Fellows of NTMP, the Dzerzhinsk Plant and CSRIFMI) - permits to determine the speed of individual components of the charge on any section of the shaft. The diagram of the test in the study of the speed of motion of the charge with eight points of investigation is shown on Fig. 6. Radioactive granules of the charge were brought in to the level of filling, at a desired distance from the centre of the furnace, while at horizons I - VI were introduced radiometric soundings consisting of a system of three coaxial pipes, between which there is provided the circulation of water, which maintains in the interior pipe a temperature not more than 40°. In the interior pipe, which is sealed hermetically against the seepage of moisture, there is arranged a radiation detector (a self-quenched counter).

When traced charge granules are lowered from the upper horizon, the radioactivity is recorded in succession on the

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lower horizons. The speed with which the charge is moving on separate sections of the furnace is determined by the time intervals between maximum intensity of radiation, which correspond to the passage of a granule through two adjacent horizons, or by the speed of the growth of intensivity at each horizon. For the location of the detector three variants are used: a. Outside the shaft, at the furnace hood; b. In the shaft lining; 3. In the interior of the furnace.

The method of radiometric sondage was used on large volume furnaces. Tests revealed the displacement of the charge to the furnace centre at the second horizon, which was somewhat greater for coke than for ore. Between the second and third horizons both coke and ore deflect towards the periphery, the coke further than the ore. In the lower portion of the shaft materials also get displaced towards the periphery. In the axial zone the speed at which the materials were lowering was in some sections higher than at the periphery. In the tuyere zone the movement of materials was investigated by means of soundings inserted through the tuyeres. It was found that radiation sources in one minute both approach the tuyere nozzle and move away from it many times.

In the study of the motion of limestone on a furnace of medium volume it was found that the speed with which it moves decreases while it is being lowered; the limestone speed is maximal between the first and second horizons. In the lower part of the shaft at a distance of about 3.7 m from the wall limestone gets lowered faster than at the periphery: the lowering speed at a datum 20,520 at the periphery was 3 M/h, while at a distance of 2.5 m from the wall it was about 5.5 m/h.

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4. Motion of Cast Iron in a Hearth of a Large Blast-Furnace

By the method of radioactive indicators may be investigated both the intermixing of smelting products and the motion of cast iron in the blast-furnace hearth.

The method is based on the following principle. A radioactive isotope phosphorus-32 is introduced through the tuyere into the liquid cast iron and slag, which is in the hearth. Conclusions as to the nature of the motion of cast iron in the hearth are reached by the results of measurement of radioactive probes selected in definite time intervals. The present work was conducted at the Ilich Plant blast-furnace having a volume of 1,719 cu. metres. The results of investigation are shown on Fig. 7. Different amounts of the radioactive indicator were applied in different tests. Therefore, on the axis of ordinates of Fig. 7 is laid off the radioactivity of samples expressed in percentages of the maximum radioactivity for each test. The weight of cast iron output is taken to be 100%, while the time of selection of cast iron samples is also shown in relative units, taking into account the duration of the output.

On the basis of the investigation made it was established that in the intervals between outputs cast iron in the hearth of the blast-furnace is mixed poorly. Some mixing and evening out of the temperature of cast iron and of the chemical composition takes place, in the main, in the period of its outlet, as a result of the motion of cast iron in the hearth, and while it passes through the cast iron tap. When it is let out of the blast-furnace hearth, cast iron comes out first from the region of the cast iron tap and last of all from the region

of the hearth at the side of air heaters. In this process the upper layers of cast iron move considerably faster than the lower ones. When the central part of the furnace operates actively and when the cast iron tap is in a normal state, the rate with which the hearth is freed of cast iron is the same both for a furnace with a volume of 1,033 cu m and for a furnace with a volume of 1,719 cu m. Practically from 10 to 15% of cast iron, which did not come out during the output of cast iron, remains in a blast-furnace, which has a useful volume of 1033-1719 cu m, which does not influence to any considerable degree the operation of the furnace.

From the point of view of completeness of outflow of cast iron out of a furnace during output there is no need in providing a second cast iron tap for furnaces with a volume of 2,286 cu m having a 10.3 m hearth diameter. When the furnace has a larger output and cast iron is let out frequently, the normal working state of the tap can be ensured by the utilization of high-quality carbon steel for the tap and of powerful electrical guns (with an 80 kg/cm^2 piston pressure).

Cast iron is completely changed in the furnace on an average of from 2 to 3 outputs, although some insignificant amount of cast iron still remains in the furnace. That is one of the factors conditioning both the thermal inertia of a blast-furnace hearth and the gradual change of the chemical composition of cast iron.

The change of the temperature of cast iron while the output proceeds is one of the indications of the completeness with which the hearth is being freed of smelting products. During cast iron output, especially on a large furnace, the inconsiderable and temporary cooling of cast iron, which

evidences a local cooling of the hearth, remains unnoticed, just the same as the beginning of important cooling of the hearth. For the prevention and timely liquidation of possible coolings and for the maintenance of a more stable heat state of the hearth it is necessary to keep up constantly a greater heat in the central part of the hearth and to heat the hearth from tuyere to tuyere evenly, by means of selecting the corresponding systems of loading and operating duty of the rotating charge distributor, as well as to equip the blast-furnaces with instruments for the automatic measurement and recording of the temperature of cast iron and slag in the run of the output.

5. Control of the Scouring of the Lining of Blast-Furnaces

At a number of plants the methods of radioactive inserts and of radioactive sondage are used for controlling the wear of lining of the hearth bottom and of the shaft of blast-furnaces, in order to investigate the strength (resistance to wear) of refractories and select a rational design of the blast-furnace.

By the utilization of radioactive indicators quantitative data on the wear of a definite layer of shaft lining of a blast-furnace can be obtained and the time required for the destruction of the given layer determined.

The use of radioactive isotopes in the study of the wear of blast-furnace hearth bottom linings led to the mastery of the dynamics of wear and permitted to set up a rational shape of the hearth bottom.

Hearth bottoms, which are cylindrical in form and have coolers along the periphery of the lower part, have the greatest strength. Hearth bottoms having the shape of a trunca-

ted cone offer less favourable conditions for cooling and get destroyed quicker. It was found advisable to use radioactive isotopes for the control of scouring of blast-furnace hearth bottoms in those cases when the hearth bottom installed is of a new design. Lately such an investigation was conducted at the Ilich plant, where the hearth bottom was made of a high-strength high-aluminous brick. Preliminary results indicate that such a hearth bottom is stronger than a chamotte hearth bottom. Due to the data of this work Design Offices have provided stronger hearth bottoms.

II. STEEL SMELTING

1. The Study of the Absorption of Sulphur Out of Gaseous Fuel in Smelting Steel in Open-Hearth Furnaces

At the Stalinsk Iron and Steel Plant the mixed coke and blast-furnace gas, used in heating the Open-Hearth furnaces, has before the headpiece from 5 to 8 g of sulphur per cu m, while before it enters the head - about 0.8 g of sulphur per cu m. In the process of smelting the sulphur is from its gaseous phase partially transformed into metal, due to which its concentration in finished steel is raised.

Below are presented: a description of the method of determination of the amounts of sulphur, which pass from the gas into the charge in smelting in Open-Hearth furnaces at the Stalinsk Plant, and of the results obtained by it.

The method is based on the determination of the weight of liquid metal and liquid slag in the furnace in the process of smelting and upon a subsequent preparation of a material balance, by sulphur, with the utilization of the data of chemical analyses of samples of both metal and slag.

The weight of both metal and slag is determined by the method of Isotope Dilution. In experimental melts a radioactive cobalt in a non-metallic state was introduced, to an amount of 0.1 m Cu per ton of metal, into liquid cast iron before it is poured into the Open-Hearth furnace. In the process of smelting metal samples were selected in the furnace and poured into the cast iron mould. Cylindrical ingots so obtained were placed in the centre of a protecting chamber, along whose circumference 12 gas counters were arranged. As the melting went on the radioactivity of metal samples kept on decreasing due to the increase of the amount of metal in melting scrap.

The weight of the total amount of liquid metal in tons M_t in the furnace at the time instant t was calculated from the results of measurements of ingot radioactivity by means of the following equation:

$$M_t = \frac{M_0 \cdot i_0}{i_t}, \text{ where}$$

M_0 - is the weight of the liquid cast iron poured into the furnace, in tons;

i_0 - is the speed of counting from a sample of that cast iron, in imp/min.g.;

i_t - is the speed of counting from a sample of metal selected out of the furnace in a time instant t , imp/min.g.

The change of weight of liquid metal in the run of one of the experimental melts is shown graphically on Fig. 9.

For the determination of the weight of liquid slag in the furnace radioactive calcium was used; it was placed into metal cartridges as CaO and arranged on the surface of solid charge materials on the bottom of the Open Hearth before cast iron was poured. The Ca^{45} content in the final slag was 7 m Cu per ton.

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As the melting went on slag samples were taken. The measurements of calcium radioactivity in slag samples, together with the calculation of the weight of the wetted slag, permitted to determine the weight of liquid slag in the furnace in the process of smelting.

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On Fig. 10 on coordinates counting speed - time is given the curve of dilution of radiocalcium in slag in one of the experimental melts.

t
In all test melts slag was weighed after the melt was completed and the ingot weight determined. That permitted to correct results of radioactivity measurements. The totality of experimental data on radioactivity and of the results of the chemical analysis of all samples of metal and slag for sulphur content permitted to make up balance sheets of melts for that element. Thus, the amount of sulphur, which went over from the fuel into the charge, can be determined as the difference between the actual weight of sulphur in the metal-slag system and the weight of sulphur carried into the furnace along with charge materials.

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12 melts have been investigated by the method described. It was found that during the periods of heaping up, warming and pouring cast iron the open-hearth bath consumes on the average about 3 kg of sulphur per hour, or approximately 11 kg during that entire period. That makes up approximately 15% of the total weight of sulphur in the metal-slag system.

During the melting period the bath consumes somewhat more of sulphur, the amounts consumed increasing with the growth of the sulphur content in the mixed coke and blast-furnace gas.

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The results of calculations indicate that during the period of melting, the metal, on an average, absorbs about 11 kg

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of sulphur from the fuel, while in the period of final melting about 1.5 kg of "gaseous" sulphur passes over from the metal into the slag. In all during the melt from fuel into steel passes over about 20 kg of sulphur, which is approximately 0.015%.

Usually in melts made under conditions as described above the ready metal has a sulphur content of 0.045%. Thus, on the average, approximately one third of that amount is the component that gets into steel from the fuel. However, if we turn from average values to the consideration of individual melts, then we will note that in some cases during the period of final melting there is observed a considerable decrease of the sulphur content in the metal. So, in one of the test melts in this period about 13 kg of "gaseous" sulphur was removed from the steel, i.e., almost 0.010%. The result obtained indicates that there is a possibility to considerably lower the steel sulphur content by means of bettering the slag regime. It was found that the greatest negative effect upon the process of desulphuration is produced by the slag silica content, the silica entering the slag from the ore charged into the furnace. In that connection the Stalinsk Plant introduced the practice of changing a part of the ore by cinders, which contain no silica. Such a modification of the technology ensures a substantial lowering of the metal sulphur content and a lessening of the duration of melts.

At the present time operations, in which the weight of liquid steel in the furnace has to be determined, are carried out by the utilization of radioactive ruthenium in place of radiocobalt. In that determination the intensity of radiation of metal samples is measured by means of a scin-

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tillation counter, which permits to decrease more than an
order the concentration of the radioactive isotope in the
metal.

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2. The Study of Slag Formation in Smelting Steel in
bove
Large Open-Hearth Furnaces

The "Azovstal" Iron and Steel Plant processes cast iron
with a high phosphorus content. Therefore, the rationalization
of the Open-Hearth furnace slag regime is of especial interest
ve
to it, in order to most effectively dephosphorise the metal,
as well as to obtain slags with a high content of phosphorus
pentoxide, used as agricultural fertilizer.

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of
In the open-hearth shop a technology was specified, by
which in the furnace, after the ready steel is let out, some
amount of slag is left. That measure is aimed to facilitate
ned
the formation of slag during the melting period in the next
melt. The optimal conditions for the utilization of such a
slag were worked out by means of the method of radioactive
isotopes. To the slag, which was left in the furnace, radioac-
a
tive sulphur was added, and then, as the process of melting
was being carried on, slag samples were taken. By the results
ro-
of measurements of the radioactivity of these samples it was
established that the earlier the slag, which was left over in
ogy
the furnace, begins to melt, the more successful is the flow
of the dephosphorization process.

In this connection the idea occurred that the openhearth
slag, which is skimmed from the furnace in the final period
of bath refining, may again be used in subsequent melts as a
slag forming material. In this case the slag, which previously
was dumped on the heap, now becomes a circulating material,
n-
which permits to reduce the consumption of limestone. Besides,

the use of such a formed slag should facilitate the melting of ore and limestone charged into the furnace and, therefore, should better the conditions of dephosphorization of metal during the initial period of melting.

Below are described tests on Open-Hearth furnaces of the "Azovstal" Iron and Steel Plant, in which the speed of melting of the circulating slag and its effect upon the run of melting were determined. For that purpose the circulating slag was traced with radioactive phosphorus. From 30 to 40 minutes before the last polished slag was skimmed, into the metal bath have been introduced a few grams of iron phosphide enriched P^{32} . In the interval up to the end of the melt radioactive phosphorus was oxidized and was uniformly spread in the liquid slag volume. When poured out of the furnace the slag was subjected to crushing in the ram engine shop to sizes of 50-100 mm and was then used in melts. The amount of this slag, which was charged into the furnace, was from 1.5 to 4% by weight of the metallic part of the charge.

The judgment of the speed of melting of the solid slag was made by the radioactivity of slag samples, which were taken from the furnace in the process of melting. Tests have shown that the first samples of slag, taken directly after the pouring of cast iron, were characterized by a maximal radioactivity. That can be illustrated on Fig. 11, on which is given a curve indicating the variation of radioactivity of slag samples with the run of the melting. From an analysis of this Fig. it follows that the circulating slag almost entirely passes into the liquid state directly after the pouring of the cast iron into the furnace. Thus, an analysis of the above mentioned tests shows that the use of circula-

ting slag should lead to the contraction of the duration of melting. A comparison of melts made by the usual and by the new technology corroborated that assertion. It showed that in the last case on the average the duration of melts has been lessened considerably. Taking into account the lessening simultaneously of the consumption of limestone, it may be considered that the new technology possesses important economic advantages. At the present time it is being mastered by the plant.

3. The Effect of the Quantity of Slag Upon the Quality of Steel in the Period of Pure Boiling

At the "Azovstal" Iron and Steel Plant the radioactive isotope of phosphorus was also utilized for the determination of the weight of slag in an open-hearth furnace in the period of pure boiling. Radiophosphorus was introduced into the furnace in the middle of that period. The weight of slag was determined by the measurement of the radioactivity of its samples.

Tests have shown that the flow of processes of steel melts and the quality of the ready metal both depend upon the quantity of slag in the furnace. So, Fig. 12 shows that the speed of oxidation of carbon, when all other conditions are the same, is a maximum for mean quantities, of slag comprising about 6% of the weight of the metal. Both for greater and for smaller quantities of slag the oxidation is retarded.

It is interesting to note that with such an optimal quantity of slag in the furnace there also is observed a maximal speed in the heating of the metal and a highest output of steel of the first class. That can be illustrated by Fig. 13, on which the output of first class rails is shown to be a function of the weight of slag in the furnace.

Conclusions

The examples presented in the report indicate the effectiveness of the utilization of radioactive isotopes in the solution of technological problems of metallurgical production.

The further advance of works on the utilization of the attainments of nuclear physics for the benefit of metallurgy will, seemingly, to a considerable degree depend upon the results of the activities of scientists and engineers in the field of physics of the isotopy of elements and of nuclear radiation, as well as the achievements in the design of radiometric apparatus and of individual nuclear physics installations. Here should, in the first place, be named such questions as the availability of radioactive and stable isotopes of a series of light elements, which can be handled conveniently, the design of high-sensitive portable radiometric apparatus which will make possible to conduct measurements on a wide range of temperatures, the creation of small-size powerful neutron sources. With greater intensity should the development of questions connected with radiation safety in working with isotopes and radiation, under conditions of industrial production, be continued. Exchanges of experiences obtained in various countries on the above-indicated questions of applied nuclear physics may substantially accelerate the advance of this field of science and technique.

Figures

Fig. 5. Distance from wall, mm.

Fig. 6. 1) Horizons;
2) To tuyere No. 8;
3) To tuyere No. 9;
4) To tuyere No. 8;
To horizons I-V.

Fig. 7. 1) Radioactivity of cast iron tests, %%;
2) Weight of cast iron melt, %.

Fig. 9. 1) Scrap smelting melt No. 3161;
2) Weight in tons;
3) Time in minutes.

Fig. 10. 1) Melt No. 3149;
2) Dilution Ca^{45} ;
2) $\frac{\text{imp.}}{\text{min.}}$;
3) Time, min.

Fig. 11. 1) $\frac{\text{imp.}}{\text{min.}}$;
2) Time, hour-min;
3) Pouring

$\begin{array}{ccc} \text{I} & \text{II} & \text{III} \\ \downarrow & \downarrow & \downarrow \\ \text{cast iron} & & \end{array}$

Fig. 12. 1) 0 - rail steel
X - low carbon steel;
2) Speed of burning of carbon, % Cmin.;
3) Percent of slag from weight of metal.

Fig. 13. 1) Percent of first class rails;
2) Percent of slag from weight of metal.

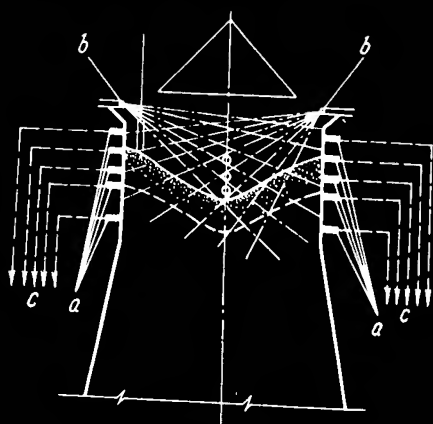


Рис. 1

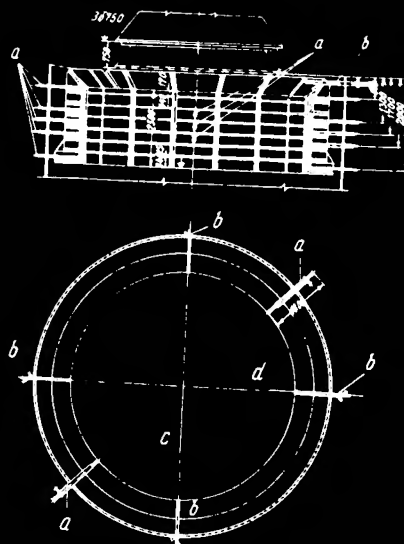


Рис. 2

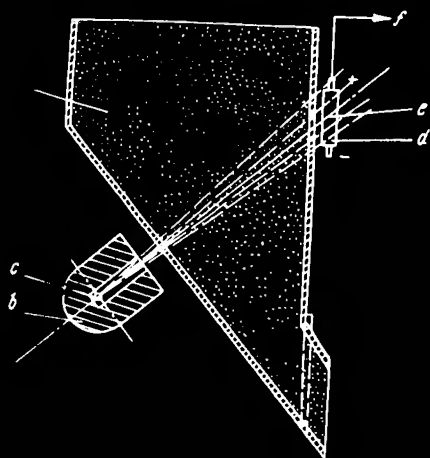


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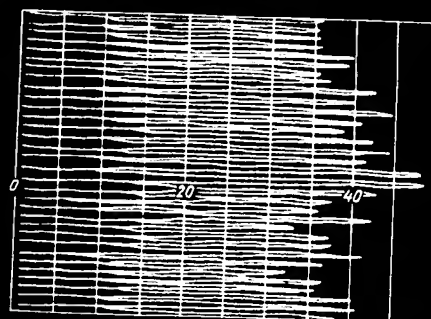


Рис. 4

367.2

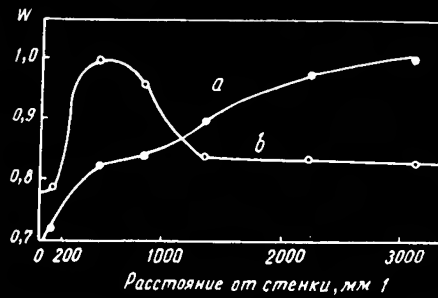


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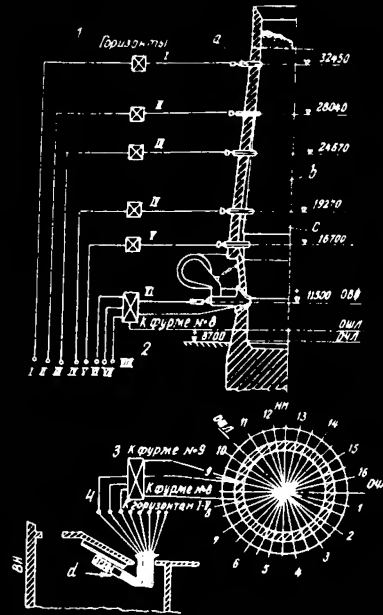


Рис. 6

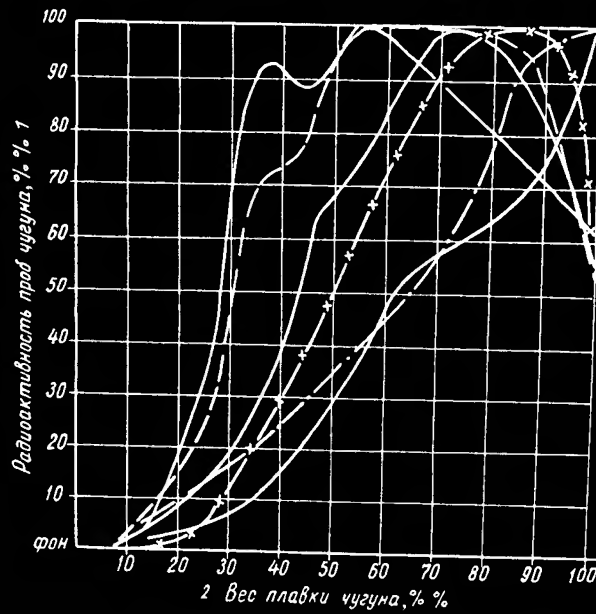


Рис. 7

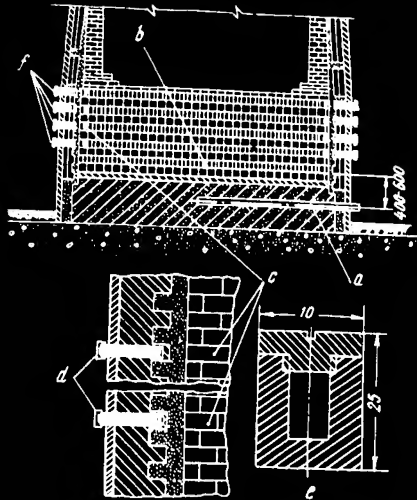


Рис. 8

1 ПЛАВЛЕНИЕ СКРАПА
П.Л. N3161

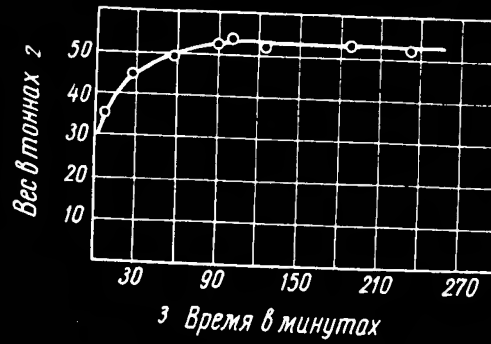


Рис. 9

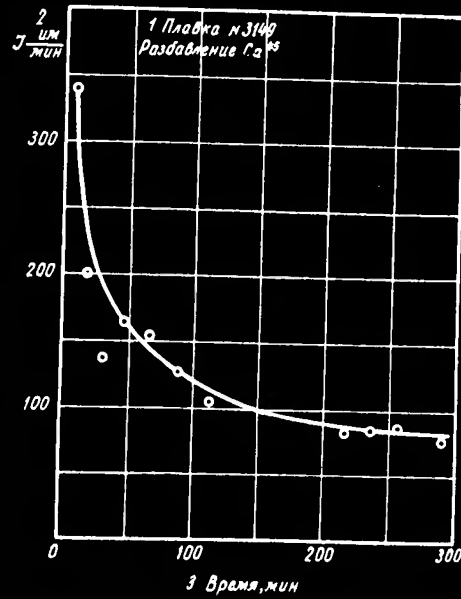


Рис. 10

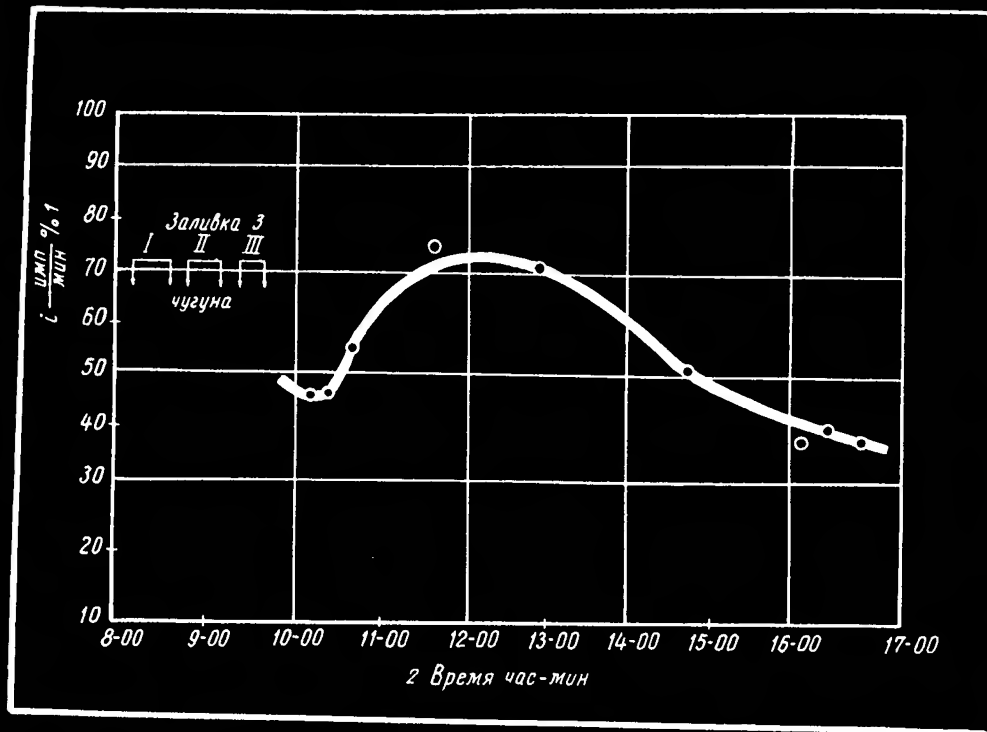


Рис. 11

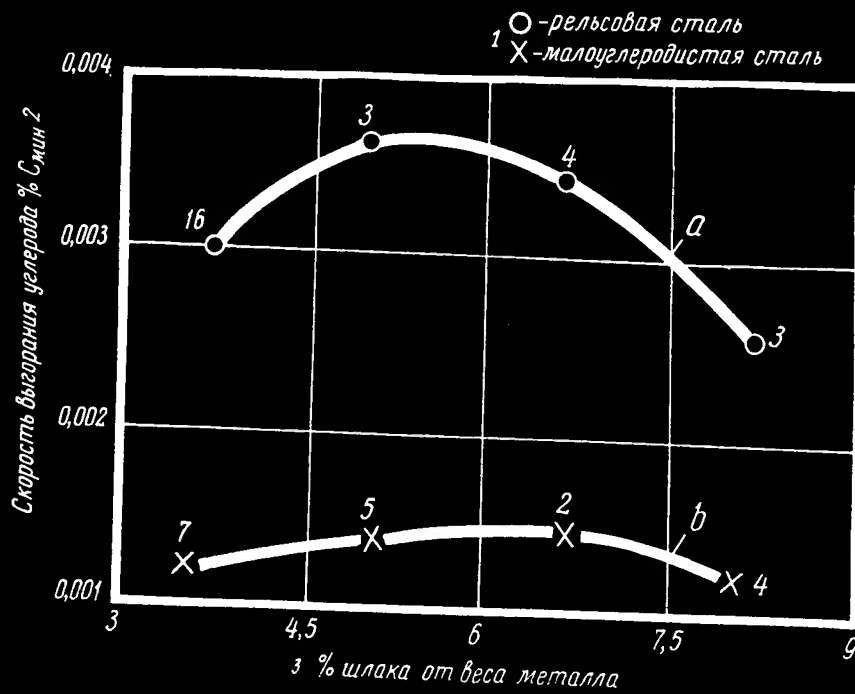


Рис. 12

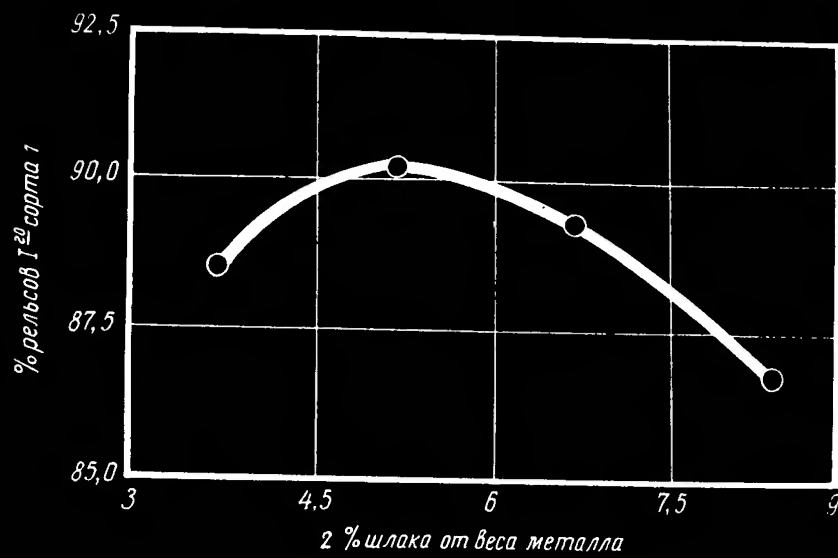


Рис. 15

THE USE OF IONIZING RADIATION FOR MODIFYING THE
PROPERTIES OF WOOD AND SYNTHETIC POLYMERS
by V.L.Karpov, A.S.Freidin, Y.M.Malinskij, V.I.Serenkov,
R.S.Klimanova

A practically important trend in the field of radiation chemistry is the research into the use of nuclear radiation to obtain new types of polymeric materials. To this heading belongs the work in polymerization and the study of the effect of nuclear radiations on natural and synthetic polymeric materials; radiation vulcanization and graft-polymerization; and the production of block-polymers through irradiation.

Great emphasis has been laid in the recent period on the development of methods of how to apply nuclear radiation to produce graft- and block-polymers. The principal process underlying these methods is a modification of the properties of polymeric materials either by "grafting" chains of a different chemical composition and structure to the molecular chains of polymers or by producing block-polymers of varying structure. Among the methods known so far of producing grafted co-polymers the least elaborated is the method of irradiating mixtures of polymers in solid state or in solution.

The application of ionizing radiations for processing and modifying wood and other materials is based, on the one hand, on an examination of properties of the irradiated wood and on the other - on employing radiation polymerization and graft-polymerization.

Of greatest interest is the modification process of wood and other fibrous or porous materials after previously impregnating them with a monomer. An irradiation following the impreg-

nation produces a radiation polymerization of monomers and in some cases even a formation of grafted polymers, the resulting products having a different set of properties.

Some of the characteristic advantages of this technique are: a possibility of performing the process at room temperature, atmospheric pressure, and without using catalysts and initiators, and a low viscosity of monomers, a factor which facilitates the impregnation process.

By varying the choices of monomers, the extent of their impregnating the fibrous base, and the conditions of irradiation it is possible to obtain materials with extremely different properties which combine the characteristics of the initial product with those of the polymer formed.

We have studied in particular the modification of wood by polystyrene, polymethylacrylate, polymethylmetacrylate, polyvinylacetate and polyacrylonitril. The most interesting results are observed when the polymer can be solved in its monomer.

If compared with popular kinds of wood plastics (DSP, delta-wood a.o.) this material is characterized by full retention of the cell structure of wood presenting a framework which is filled with the newly formed polymer.

Below are given the properties of modified wood (pine-wood, modified with polystyrene). The volume weight of the material increases from 0,46 to 0,61 when the amount of styrene absorbed is 20,5% of the weight of wood and from 1,0 to 1,1 when the wood has absorbed 120% of polystyrene.

Table 1 shows varying strength characteristics of such wood.

Table 1

Polystyrene: 120% of the weight of wood

Dose rate: 22 rad/sec

Property	Integral dose, 10^{-6} rad		
	0	15,5	50
Resistance to compression along fibre, kg/cm^2	325	920	1050
Resistance to static bending, kg/cm^2	845	1400	1135

It follows from Table 1 that the most substantial improvement of strength corresponds to the integral dose of $15,5 \cdot 10^{-6}$ rad. Further irradiation decreases the resistance of wood against static bending which is a result of alterations occurring in wood itself due to γ -rays (see below).

Along with the integral dose the intensity of irradiation is of major importance for the qualities of the product obtained.

As is shown in Fig. 1-2, the formation in the wood of such a water-resistant polymer as polystyrene decreases more than twofold the maximum moisture absorption of wood and more than sixfold its water absorption. The maximum water absorption (within 30 days) of such wood is not more than 25%, and the volume increase due to moisture absorption (see Table 2) is twice less as compared to the initial material.

Table 2

Change of volume in determining moisture absorption
of pine-wood modified with polystyrene
Integral dose $15,5 \cdot 10^{-6}$ rad

	Time, days							
	1	2	3	5	8	13	20	30
Change of volume of modified wood, % of the initial	4,2	6,5	5,4	7,4	4,9	8,2	6,8	6,9
Change of volume of basic wood, % of the initial	9,7	11,8	11,2	14,0	12,9	15,0	14,0	15,0

The wood modified with polyacrylonitril possesses high fire resistance and will not give food to burning. Thus the above method makes it possible to obtain from both hard and soft wood varieties such materials which differ from the initial ones by increased strength, chemical resistance, a lower water and moisture absorption and a greater dimension stability. Such a wood is fungi-resistant and, using appropriate polymers, is provided with better dielectrical qualities.

Materials of this kind may find many applications in building, transport, engineering, electric and radio industry. In particular, a specially conducted test of the adequacy of wood modified with polystyrene for making casting models (bearing model 350x150x200 mm) has shown that after 18 days in moulding earth such models practically do not change their shape or dimensions and absorb twice less moisture than samples not processed. They have several characteristics superior to models protected by other techniques.

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The polymerization of monomers by ionizing radiation can be performed not only in wood but also in other fibrous materials: textiles, paper etc. with considerable alteration of qualities resulting. An interesting application of this method of material modification is the conservation of all kinds of museal and archeological treasures composed of fibrous material by using radiation polymerization.

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0
The development of a practical application of ionizing radiation for wood modification has been made possible due to extensive research into the radiation acting on the lignin-carbo-hydrate complex and its components. The change of the mechanical properties of various wood varieties has been studied with great detail, and the dose limits leading to an essential decrease in wood strength have been defined (Table 3).

Apparently, these dose-rates are considerably higher than those necessary for modifying wood by radiation polymerization and graft-polymerization.

γ -radiation results in somewhat higher rates of water absorption (though its maximum value remains constant) and a certain decrease of water vapour absorption (2-3%) by wood.

The change in the mechanical properties of irradiated wood is caused by radiation-chemical processes which take place in irradiated materials. These processes result in a higher solubility of these materials in water which is in the main a consequence of a destruction of the polysaccharides macromolecules down to the level of low-molecular products.

The radiolysis affects in the first place the hemicelluloses and among these - the pentosans, with cellulose second. Lignin is the most radiation resistant component protecting carbo-hydrates from radiolysis.

In scale of radiation resistance the polysaccharides are to be arranged as follows:

araban < xylan < mannan < galactan < cellulose

As is known, lignin is responsible for the resistance of wood against compression, while the cellulose and the hemicelluloses in the first rate make it resistant against splitting and bending stresses. That accounts for the irradiated wood working better against compression and worse against bending and splitting.

We have also studied the possibilities of using nuclear radiation for producing new types of polymers based on mixtures of high pressure polyethylene and block-polystyrol.

The initial polyethylene and polystyrene were mixed by rolling at 140°C, in weight proportions 90: 10 (PS - 10); 80:20 (PS - 20); 50:50 (PS - 50) respectively.

From these rolled mixtures samples for irradiation and subsequent test were prepared by casting or pressing. The irradiation of samples was made using a Cobalt⁶⁰ source of 21.000 g.eq. of Ra, at 20°C and 130°C with and without atmospheric oxygen.

The samples were tested for tension strength and elongation in tension prior to and after the irradiation. The change of the specific impact toughness was also measured. In the latter test there was no destruction of the PS - 10 nor PS - 20 samples neither prior to, nor after the irradiation.

The changes in the mechanical properties of the polymers concerned after their irradiation are presented in Table 4. The total quantity of ungrafted and non-cross-linked polystyrene was determined by extracting irradiated samples with toluol in a Soxhlet apparatus for 12 hours.

Table 3

The Effect of Ionizing Radiation on the Strength of Some Wood Varieties

Property	Integral Dose										
	0	10		50		100		300		500	
	Strength limit, kg/cm ²	Strength limit, kg/cm ²	Change of strength, %	Strength limit, kg/cm ²	Change of strength, %	Strength limit, kg/cm ²	Change of strength, %	Strength limit, kg/cm ²	Change of strength, %	Strength limit, kg/cm ²	Change of strength, %
<u>Resistance to compression</u>											
Pine-wood	350	360	0	385	+5,5	350	-4	320	-12,5	250	-33
Asch-wood	520	-	-	-	-	450 ^{*/}	-16,5	410 ^{*/}	-21	-	-
Beech-wood	655	-	-	-	-	570	-18,5	500	-24	-	-
<u>Resistance to splitting</u>											
Pine-wood	75	70	-6,5	57	-24	39	-48	32	-57	22	-70
Asch-wood	150	-	-	-	-	105	-30	100 ^{*/}	-34	-	-
Beech-wood	85	-	-	-	-	-	-	27 ^{*/}	-68	-	-
<u>Resistance to statical bend</u>											
Pine-wood	825	800	-3	660	-20	370	-55	250	-70	83,5	-90
Asch-wood	920	-	-	-	-	-	-	230 ^{*/}	-64	-	-

*/ Dose-rate 140.

**/ Dose-rate 380.

Table 4

Change of Mechanical Properties of Polymers Due to Irradiation

Type of material	Non-irrad.				Dose-rate												
	Tension strength, kg/cm ²	Elongation in tension, %	Specific impact toughness, kg/cm ²	G	100		200		300		400		500				
					G	ε	Specific impact toughness, kg/cm ²	ε	Specific impact toughness, kg/cm ²	G	ε	Specific impact toughness, kg/cm ²	G	ε	Specific impact toughness, kg/cm ²	G	ε
Polyethilene	111	350	-	-	-	-	155	80	-	161	70	-	160	50	-	-	-
PS - 10	90	75	-	163	69	-	172,5	65	-	200	54	-	175	45	-	169	40
PS - 20	88	62	-	113	35	-	161	23	-	176	20	-	183	20	-	168	15
PS - 50	78	57	14	92	10-15	27,2	161	5-7	53,5	-	-	-	162	5-7	61	160	5-7

Though part of the ungrafted and non-cross-linked polystyrene could not be extracted because it was immobilized in cross-linked polyethylene, the measurement was adequate for making certain conclusions about the interaction of polyethylene and polystyrene during the irradiation.

In particular, an examination of the extract of a sample PS - 10 which had received a dose of $60 \cdot 10^{-6}$ rad has shown that under the conditions above mentioned not only the whole of the polystyrene contained in the sample is extracted but also 8-10% of polyethylene.

Part of the polyethylene thus extracted (50-60%) is precipitated when the extract is cooled. The remaining 50-40% of the extracted polyethylene is isolated during fractionation by adding methyl alcohol to the extract in quantities insufficient for the precipitation of polystyrene. The findings of the elementary analysis of this precipitate testify to an interaction of polyethylene and polystyrene taking place during irradiation. The fact of such interaction is also confirmed by the results of thermo-mechanical tests of irradiated and non-irradiated polystyrene, polyethylene, PS - 10, PS - 20, and PS - 50. In the PS - 10 and PS - 20 samples which had received for example a dose of $500-700 \cdot 10^{-6}$ rad a certain, though not considerable, increase of the elasticity module is observed in atmospheric conditions as against that for pure polyethylene, which fact can be accounted for solely by an interaction of polyethylene and polystyrene during irradiation.

The irradiated mixtures of polyethylene and polystyrene show a $35-40^{\circ}\text{C}$ increase in the temperature of change to con-

dition of high elasticity as compared to the temperature of the initial mixtures changing to viscous condition. An examination of the solubility of irradiated pure polyethylene and its mixtures with polystyrene has shown that polystyrene produces a stabilizing effect on polyethylene as a result of which the rate of tying polyethylene in the presense of polystyrene decreases.

We have also examined the thermal stability of the samples PS - 10, PS - 20, and PS - 50 which had been irradiated in the air with a dose of $1000 \cdot 10^{-6}$ rad, by heating them at 250°C for 4-6 hours. In all cases a change of colour was observed but no change of form, of the samples.

In order to achieve a fuller combination of polystirol, and polyethylene, reduce the viscosity of the medium and make condition more favourable for an interaction of polyethylene and polystirol, we irradiated samples of PS - 10, PS - 20 and PS - 50 at a temperature of 130°C . At this temperature the above mixtures of polyethylene and polystirol changed, according to visual observation, to homogenous and transparent melts.

However, at these conditions, intense gase formation occurred during irradiation which resulted in porous materials. Thus, by irradiating mixtures of polyethylene and polystirol at room temperature one can obtain new types of polymeric materials with improved strength and thermal stability characteristics (up to 250°C).

The resulting irradiated materials are not amenable to known technological processing techniques and the method

na- of increasing thermal stability and strength characteristics
ces just described is only applicable to previously shaped products.

Materials of this kind may find application in radio-engineering and electrotechnics and also where it is necessary to improve radiation stability of a product made for instance of polyethylene.

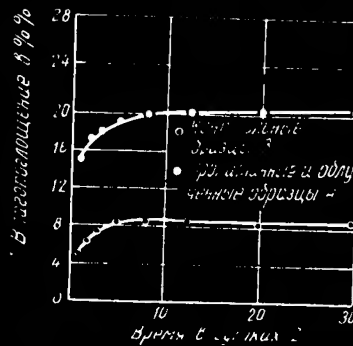


Fig. 1. Change of moisture absorption of initial and modified wood (on a time basis).

1 - Moisture absorption, %; 2 - Time, days; 3 - Control samples; 4 - Impregnated and irradiated samples.

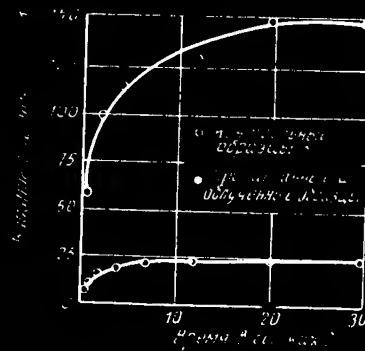


Fig. 2. Change of water absorption of initial and modified wood (on a time basis).

1 - Water absorption, %; 2 - Time, days; 3 - Control samples; 4 - Impregnated and irradiated samples.